JC14 Rec'd PCT/PTO 23 MAR 2001

FORM PTO-1390 REV. 5-93 US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEYS DOCKET NUMBER **P01,0052**
		U.S.APPLICATION NO. (if known, see 37 CFR 1.5) 09/787997
INTERNATIONAL APPLICATION NO. **PCT/DE99/01993**	INTERNATIONAL FILING DATE **01 July 1999**	PRIORITY DATE CLAIMED **24 September 1998**

TITLE OF INVENTION

METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION SIGNAL PROCESSOR AND RADIO EQUIPMENT

APPLICANT(S) FOR DO/EO/US

NORBERT LOEBIG

pplicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of International Application as filed (35 U.S.C. 371(c)(2)) - drawings attached.
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2) - drawings attached.
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report).**
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included. (Separate envelope)
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☒ A substitute specification, including red-lined version
15. ☒ A change of power of attorney and/or address letter.
16. ☒ Other items or information:
    a. ☒ Submission of Ready to publish drawings
    b. ☒ Request for Approval of Drawing Changes
    c. ☒ Express Mail Label EJ 778078625US

JC08 Rec'd PCT/PTO 23 MAR 2001

U.S.APPLICATION NO. (if known, see 37 C.F.R. 1.5) 09/787997	INTERNATIONAL APPLICATION NO. **PCT/DE99/01993**	ATTORNEY'S DOCKET NUMBER **P01,0052**

17. ☒ The following fees are submitted:				CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5): Search Report has been prepared by the EPO or JPO . . . . $860.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482)$690.00 No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2) . . . . $760.00 Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO . . . . $1000.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 860.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	12 - 20 =		X $18.00	$	
Independent Claims	2 - 3 =		X $ 80.00	$	
Multiple Dependent Claims			$270.00 +	$	
TOTAL OF ABOVE CALCULATIONS =				$860.00	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28)				$	
SUBTOTAL =				$860.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$860.00	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property +					
TOTAL FEES ENCLOSED =				$860.00	
				Amount to be refunded	$
				charged	$

a. ☒ A check in the amount of $860.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ____________ in the amount of $ ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 501519. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Steven H. Noll
SIGNATURE

Schiff Hardin & Waite
Patent Department
6600 Sears Tower
Chicago, Illinois 60606
Customer No. 26574

Steven H. Noll
NAME

28,982 (Registration No.)

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

AMENDMENT "A" PRIOR TO ACTION AND SUBMISSION OF SUBSTITUTE SPECIFICATION

APPLICANT:	Wen Xu
ATTORNEY DOCKET NO.	P01,0052
INTERNATIONAL APPLICATION NO:	PCT/DE99/01993
INTERNATIONAL FILING DATE:	July 1, 1999
INVENTION:	"METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION, SIGNAL PROCESSOR AND RADIO EQUIPMENT"

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Applicant herewith amends the above-referenced PCT application as follows, and requests entry of the Amendment prior to examination in the United States National Examination Phase.

IN THE SPECIFICATION:

Applicant herewith submits a substitute specification pursuant to 37 C.F.R. §1.125(b). The substitute specification does not contain any new matter. A marked up copy of the substitute specification, showing all of the changes made therein, is also submitted herewith.

IN THE DRAWINGS:

Please amend each of Figures 1, 2 and 3 as shown on the drawing copies marked in red attached to the Request for Approval of Drawing Changes, filed simultaneously herewith.

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IN THE CLAIMS:

On page 15, cancel "Patent claims" and substitute --**I CLAIM AS MY INVENTION:**-- therefor.

Please cancel claims 1-10 and substitute the following claims therefor:

11. A method for coding information consisting of symbol sequences containing symbols which occur with different probabilities, comprising the steps of:

mapping said symbols to binary code words, each having a plurality of bit positions; and

in said mapping, sorting said symbols dependent on their respective probability of occurrence, and allocating a natural code words to said symbols to obtain sorted symbols, and allocating a natural binary code to said sorted symbols.

12. A method as claimed in claim 11 wherein the step of sorting said symbols comprises sorting a substantial proportion of said symbols, thereby obtaining a substantial proportion of sorted symbols, and comprising allocating said natural binary code to said substantial proportion of sorted symbols.

13. A method as claimed in claim 11 wherein the step of sorting said symbols comprises sorting all of said symbols, and allocating said natural binary code to all of said sorted symbols.

14. A method as claimed in claim 11 wherein the step of allocating said natural binary code comprises:

allocating a code word which exhibits a first binary value at all bit positions to a symbol which occurs most frequently; and

allocating a code word which exhibits a second binary value at all positions to a symbol occurring most infrequently.

15. A method as claimed in claim 11 comprising producing said symbol sequences from a source encoding.

16. A method as claimed in claim 11 comprising interchanging bit positions of code words obtained from said mapping.

17. A method as claimed in claim 11 wherein said symbol sequences contain redundant information, and comprising decoding said natural binary code using said redundant information as a priori information for determining respective values of said bit positions.

18. A method as claimed in claim 11 wherein said symbol sequences contain redundant information, and comprising decoding said natural binary code using said redundant information as a posteriori information for determining respective values of said bit positions.

19. A method as claimed in claim 11 wherein said bit positions of said code words contain redundant information, and comprising decoding said natural binary code using said redundant information as a priori information for determining respective values of said bit positions.

20. A method as claimed in claim 11 wherein said bit positions of said code words contain redundant information, and comprising decoding said natural binary code using said redundant information as a posteriori information for determining respective values of said bit positions.

21. A signal processing arrangement for coding information consisting of symbol sequences containing symbols which occur with different probabilities, comprising the steps of:

mapping said symbols to binary code words, each having a plurality of bit positions; and

in said mapping, sorting said symbols dependent on their respective probability of occurrence, and allocating a natural code words to said symbols to obtain sorted symbols, and allocating a natural binary code to said sorted symbols.

22. A signal processing arrangement as claimed in claim 21 wherein said symbol sequences contain redundant information, and comprising decoding said natural binary code using said redundant information as a priori information for determining respective values of said bit positions.

IN THE ABSTRACT:

Please cancel the present Abstract and substitute the Abstract attached hereto on separately numbered page 17.

REMARKS:

The present Amendment makes editorial changes in the specification, claims, drawings, and Abstract to conform to the requirements of United States patent practice. All changes in the claim language have been made solely for the purpose of bringing the claims into compliance with the requirements of 35 U.S.C. §112, second paragraph, and no change in any of the claims has been made for the purpose of distinguishing any of the claims over the teachings of the prior art of record. Accordingly, no change

in any of the claims is considered by the Applicant as a surrender of any the subject matter encompassed within the scope of the claims as originally filed.

Submitted by,

(Reg. 28,982)

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Attorneys for Applicant.

ABSTRACT OF THE DISCLOSURE

In a method, and a signal processing arrangement, for coding information, the information symbol sequences are first sorted in accordance with the probability of occurrence of the symbols in the sequences, and are then mapped to the natural binary code. This allows redundant information contained in the symbol sequences to be used for decoding the bit positions.

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BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

REQUEST FOR APPROVAL OF DRAWING CHANGES

APPLICANT:	Wen Xu
ATTORNEY DOCKET NO.	P01,0052
INTERNATIONAL APPLICATION NO:	PCT/DE99/01993
INTERNATIONAL FILING DATE:	July 1, 1999
INVENTION:	"METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION, SIGNAL PROCESSOR AND RADIO EQUIPMENT"

Assistant Commissioner for Patents,

Washington, D.C.

SIR:

Applicant herewith requests approval of the drawing changes in each of Figures 1, 2 and 3, as shown on the drawing copies marked in red attached hereto.

Submitted by,

Steven H. Noll (Reg. 28,982)

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6600 Sears Tower
233 South Wacker Drive
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Telephone: 312/258-5790
Attorneys for Applicant.

09/787997

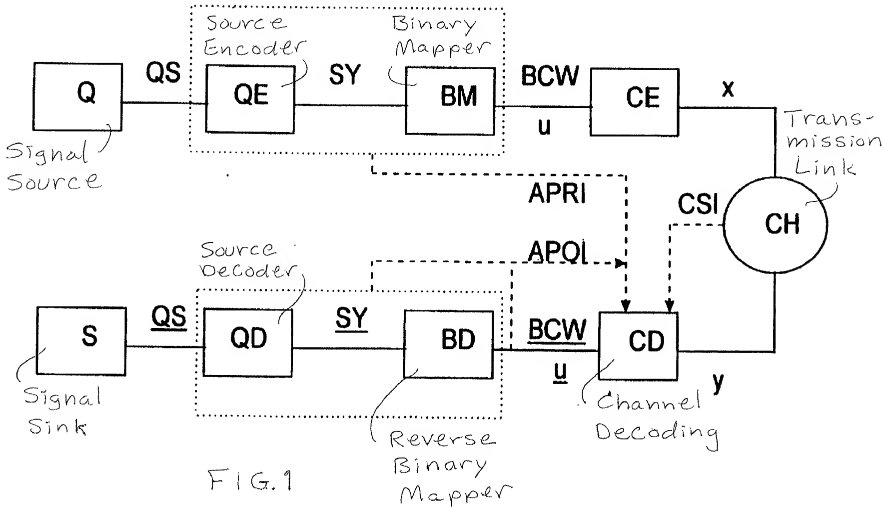

FIG. 1

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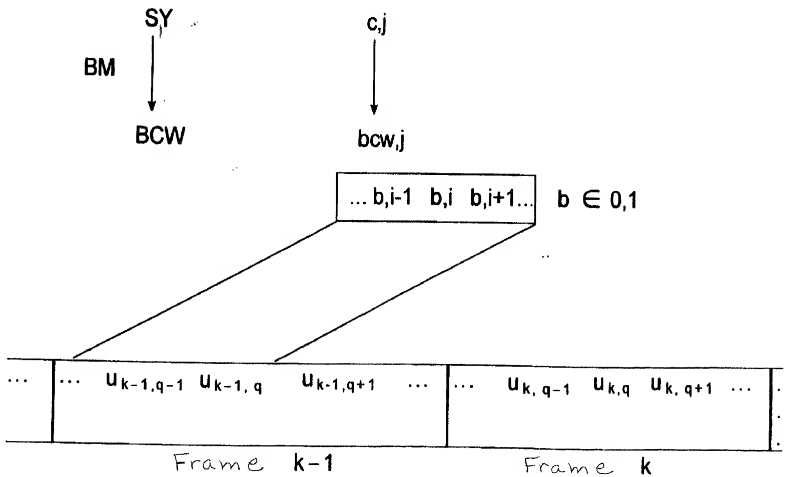

FIG. 2

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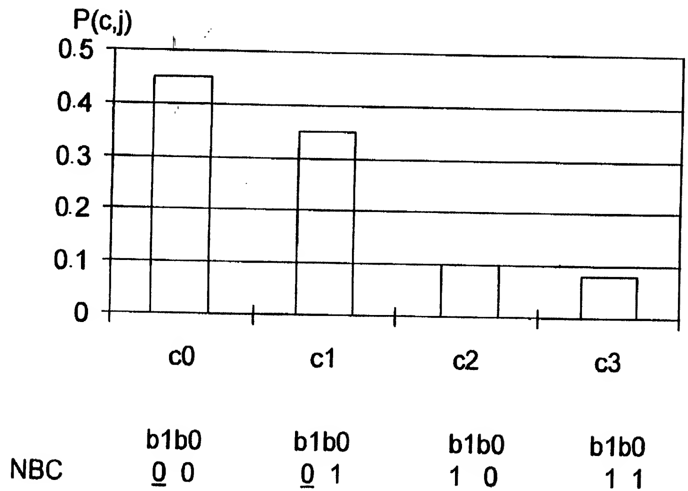

FIG. 3

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BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

SUBMISSION OF READY TO PUBLISH DRAWINGS

APPLICANT: Wen Xu

ATTORNEY DOCKET NO. P01,0052

INTERNATIONAL APPLICATION NO: PCT/DE99/01993

INTERNATIONAL FILING DATE: July 1, 1999

INVENTION: "METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION, SIGNAL PROCESSOR AND RADIO EQUIPMENT"

Assistant Commissioner for Patents,

Washington, D.C. 20231

S I R:

Applicant herewith submits three sheets (Figs. 1-3) of "ready to publish" drawings for the above-referenced PCT application.

Submitted by,

(Reg. 28,982)

SCHIFF, HARDIN & WAITE
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Telephone: 312/258-5790
Attorneys for Applicant.

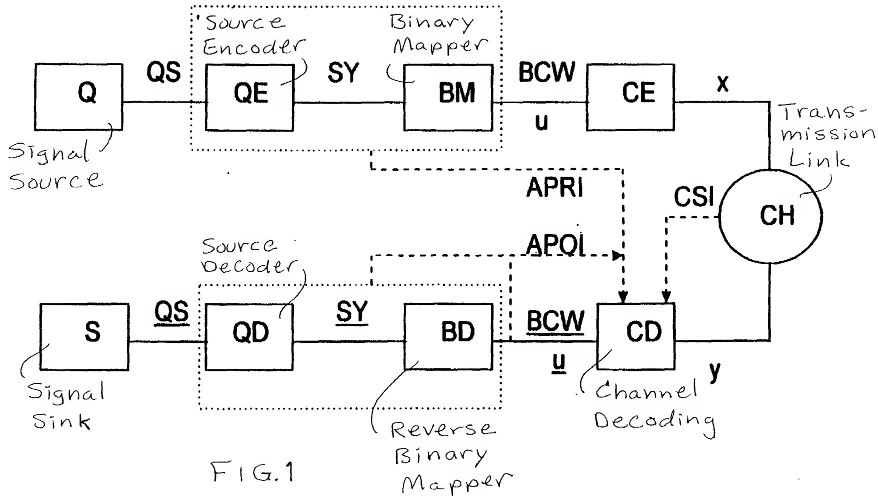
Q
Signal Source
QS
Source Encoder
QE
SY
Binary Mapper
BM
BCW
u
CE
x
Transmission Link
CH
CSI
APRI
APOI
S
Signal Sink
QS
Source Decoder
QD
SY
BD
Reverse Binary Mapper
BCW
u
CD
y
Channel Decoding

FIG.1

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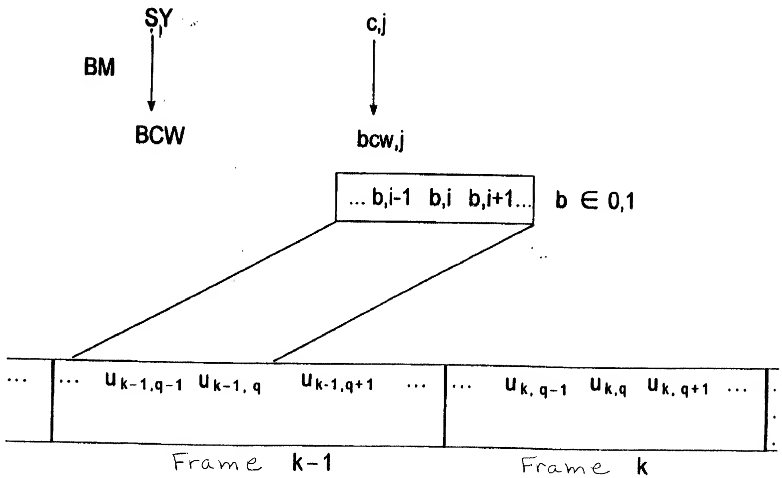

FIG. 2

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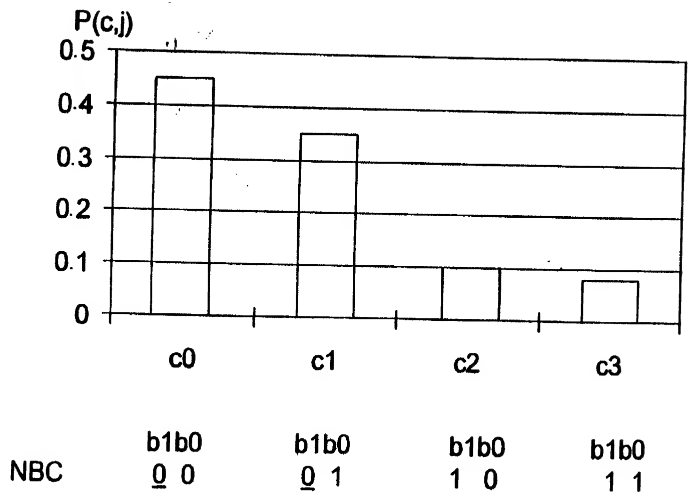

FIG. 3

SPECIFICATION

TITLE

"METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION, SIGNAL PROCESSOR AND RADIO EQUIPMENT"

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method for coding and decoding information, especially for digital transmission or storage.

Description of the Prior Art

Source signals or source information such as voice, sound, image and video signals almost always contain statistical redundancy, that is to say redundant information. This redundancy can be greatly reduced by source encoding, making it possible to transmit and/or store the source signal efficiently. This redundancy reduction eliminates redundant signal contents which are based on the prior knowledge of, for example, statistical parameters of the signal variation, before the transmission. After the transmission, these components are added to the signal again in the source decoding, so that no loss of quality can be detected objectively.

Due to the incomplete knowledge of the source signals or restrictions in the complexity of the source encoding method, the source encoding usually only can be implemented in a suboptimum way, that is to say the compressed data still contain a certain redundancy even after the source encoding. In previous methods for source encoding, the source signals are frequently compressed to form symbols or quantized parameters which are then mapped to binary code words in accordance with an

allocation rule, the allocation rule having been selected more or less randomly until now.

On the other hand, it is usual to deliberately add redundancy again by channel encoding during the signal transmission in order to largely eliminate the effect of co-channel interference on the transmission. Additional redundant bits thus enable the receiver or, respectively, decoder to detect and possibly also to correct errors.

It has long been one of the basic premises of information theory that source encoding and channel encoding can be carried out independently of one another in order to achieve an optimum result. According to this principle, the design of the source decoder depends only on the source characteristics whereas the channel encoding arrangement should depend only on the channel characteristics. This principle can be correct if the source encoder delivers statistically independent and thus uncorrelated symbols of equal probability and the decoding delay can be of any magnitude. In practical applications, however, these prerequisites are not met, as a rule. The output signal of the source encoder or, respectively, the symbol sequences output by it frequently exhibit a residual redundancy and, at the same time, the permissible delay is restricted, especially in voice transmission.

It is known to utilize this residual redundancy of the source-encoded symbol sequences in the so-called source-controlled channel decoding. In this process, the decoding process of the channel decoder is controlled, on the one hand, by the transmitted bits and, on the other hand, by a priori/a posteriori information on the

most probable value of some important source bits. The source information thus has an influence on the result of the channel decoding. In the case of the Viterbi algorithm decoding, this method is called an a priori Viterbi algorithm. When such a method is used, only the receiver needs to be modified. Thus, the printed document J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, September 1995, teaches to use the inter-frame correlation, that is to say the statistical dependence between temporally and/or spatially adjacent signal samples in the source-controlled channel decoding.

Investigations have also shown that there is residual redundancy not only between bits of successive frames but also between the bits of a parameter within a frame due to the uneven distribution of the parameter values which, in turn, is attributable to the non-stationary condition of the source signals.

SUMMARY OF THE INVENTION

The present invention has the object of achieving information transmission or information storage with the fewest possible errors and the least possible expenditure.

According to the invention, the abovementioned object is achieved.

First sorting the symbols in accordance with their relative frequency and allocating the natural binary code to the sorting result.

The invention has the result that the error rate of the decoded bits can be reduced without additional

expenditure, and thus information can be transmitted with fewer disturbances.

In the text which follows, the invention will be described in greater detail with reference to preferred illustrative embodiments. In this connection, it is especially the digital transmission of the information which is described. Nevertheless, the information can also be applied to the storage of information since the writing of information to a storage medium and the reading of information from a storage medium correspond to the sending of information and the receiving of information with regard to the present invention.

The term "decoding" is frequently used for describing the decoding of channel-encoded bit positions whilst the term "detection" is used if generally the binary values of a bit position are decided. Since the present invention is advantageously applicable to both cases, the term "decoding" also contains the process of detection within the context of the present patent application.

<u>Description of the Drawings</u>

Figure 1 is a schematic representation of a communication chain constructed and operated in accordance with the invention.

Figure 2 is a diagram showing the relationship between symbols and the source-encoded bit sequences in a frame structure, in accordance with the invention.

Figure 3 illustrates the frequency distribution of the symbols and the binary values dependent on binary mapping, in accordance with the invention.

Description of the Preferred Embodiments

Figure 1 shows a source Q which generates source signals QS which are compressed into symbol sequences SY consisting of symbols by a source encoder QE like the GSM full-rate voice encoder. Here, the symbols have one of the values c,j (symbol value). In parametric source encoding methods, the source signals QS (e.g. voice) generated by the source Q are subdivided into blocks (e.g. time frames) and these are processed separately. The source encoder QE generates quantized parameters (e.g. voice coefficients) which are also called symbols of a symbol sequence SY in the text which follows and which reflect the characteristics of the source in the current block in a certain manner (e.g. spectrum of the voice, filter parameter). These symbols have a certain symbol value c,j after the quantization.

Thus, for example, the GSM full-rate encoder generates 76 parameters, of which parameters 0 to 7 are the so-called LAR (logarithmic area ratio) coefficients which are generated during the LPC (linear prediction coding) analysis. Parameters 9, 26, 43 and 60 are similarity values for the so-called LTP (long-term prediction). Each frame also contains four XMAX coefficients (or parameters) from the so-called RPE (residual pulse excitation) analysis which change only little from frame to frame.

Due to the incomplete knowledge of the source signals or restrictions in the complexity of the source encoding method, the source encoding QE can usually be implemented only suboptimally, i.e. the symbol sequences

SY contained in the compressed information still contain redundant information.

As shown in Figure 2, the symbols of the symbol sequence SY, or the corresponding symbol values c,j are mapped by a binary mapping BM (allocation rule) which is frequently described as part of the source encoding QE, to a sequence BCW of binary code words bcw,j which in each case have a number of bit positions b,i. Thus, to each symbol value c,j, a different binary code word bcw,j is allocated which differ by having different binary values at one or more bit positions b,i. In this process, the index j identifies the different values of the symbols or the different code words and the indices i and, in the text which follows, k,q identify the position at which a corresponding value is located.

If these binary code words bcw,j are processed further, for example, successively as a sequence BCW of binary code words, a sequence u of source-encoded bit positions u_q is produced which can be embedded in a frame structure, each bit position u_q being permanently allocated to a particular bit position b,i of a particular code word bcw,j. Thus, a frame with 260 bit positions u_q is produced every 20 milliseconds, for example in GSM full-rate encoding.

Figure 2 shows a frame structure of a frame k produced in this manner. The source-encoded bit positions u_q have either the value "+1" or "-1" or "0". The index 1 runs from 0 to Q-1 within a frame, Q being the number of source-encoded bit positions u_q in a frame. In each frame, the bit positions can be divided, for example,

into three classes having different significance and sensitivity to co-channel interference.

The source-encoded bit sequences u are coded against co-channel interference in a channel encoder CE like a convolutional encoder, in such a manner that the lowest bit-error probability occurs in the most important class. For this purpose, the 50 most significant bits (Class 1a) are first protected by 3 bits of a cyclic redundancy check (CRC). The next 132 significant bits (Class 1b) are regrouped with the aforementioned 53 bits and, together, convolutionally encoded with a ½ rate together with four tail bits. The 78 less significant bits (Class 2) are transmitted uncoded.

These bit sequences that have been x channel-encoded in this manner are processed further in a modulator, not shown, and are then transmitted via a transmission link CH. During the transmission, disturbances occur, for example, fading, described by a fading factor ak, and noise, described by the noise vector N0.

The transmission link CH is located between a transmitter and a receiver. If necessary, the receiver contains an antenna, not shown, for receiving the signals transmitted via the transmission link CH, a sampling device, a demodulator for demodulating the signals and an equalizer for eliminating the inter-symbol interference. These devices are also not shown in Figure 1 for reasons of simplification. Any possible interleaving and deinterleaving are also not shown.

The equalizer outputs received values of a received sequence y. Due to the interference in the transmission via the transmission link CH, the received values have

values which deviate from "+1" and "-1", for example "+0.2" or "-3.7".

The channel encoding is cancelled in a channel decoder CD. For this purpose, the binary values of the individual received bit positions $\underline{u}_q$ and $\underline{b,i}$ are decided on the basis of the received values of the received sequence y. Apart from the channel status information CSI, the residual redundancy of the symbol sequences SY described above can be utilized in the so-called source-controlled or common channel decoding CD for correcting bit errors or, respectively, improving the decoding. In principle, there are two possibilities for this:

- In the sense of a priori information APRI, the redundant information on the frequency of the symbol values c,j, and thus also the frequency of the binary values of certain bit positions b,i, and the correlation of the symbols to each other and thus also the correlation of the binary values of certain bit positions b,i to each other, is utilized directly in the channel decoder CD in that, for example, this information is first determined by means of some test source signals in a test source encoder or, respectively, by means of a test source encoder, and this information is then stored in a storage unit allocated to the channel decoder CD and utilized for channel decoding in that it is used, for example, for determining a threshold from which, for example, the binary value "1" is decided for a value of the received sequence y.

- The redundant information on the frequency of the symbol values c,j, and thus also the frequency of the binary values of certain bit positions b,i, and the correlation of the symbols to each other and thus also the correlation of the binary values of certain bit positions b,i to each other, is determined after the channel decoding CD in the sense of a posteriori information. The a posteriori information APOI can be determined directly after the channel decoder CD or after or during the source decoding QD.

Such a method is described in "J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, Sept. 1995", especially on pages 2451 and 2452, the decoding process of the channel decoder being controlled both by the transmitted code bits and by a priori/a posteriori information on the probable value of some significant source bits. In the case of the VA (Viterbi algorithm) decoding, this method has been called Apri-VA.

For the channel decoding CD, it is also possible to use, for example, a SOVA (soft-output Viterbi algorithm). A SOVA is an algorithm which outputs not only a decision value but, furthermore, also specifies the probability with which the decided value is present.

After the completed channel decoding CD, the received channel-decoded bit sequences <u>u</u> or, respectively, the binary code words <u>bcw,j</u> contained therein are mapped back in a reverse binary mapper BD onto received symbols of received symbol sequences <u>SY</u>

which are then processed into source signals QS in the source decoding QD and are output at the information sink S.

In the text which follows, four possible different binary mappings BM are presented:

- Natural binary code NBC
- Folded binary code FBC
- Gray binary code GBC
- Minimum distance code MBC

These four binary mappings are shown by way of example with in each case 4 bit positions in the table below:

Symbol	Code word bcw,j NBC				Code word bcw,j FBC				Code word bcw,j GBC				Code word bcw,j MDC			
c,j	b3	b2	b1	b0	b3	b2	b1	b0	b3	b2	b1	b0	b3	b2	b1	b0
c0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1
c1	0	0	0	1	0	1	1	0	0	0	0	1	0	1	1	0
c2	0	0	1	0	0	1	0	1	0	0	1	1	0	1	0	1
c3	0	0	1	1	0	1	0	0	0	0	1	0	0	0	1	1
c4	0	1	0	0	0	0	1	1	0	1	1	0	0	1	0	0
c5	0	1	0	1	0	0	1	0	0	1	1	1	0	0	1	0
c6	0	1	1	0	0	0	0	1	0	1	0	1	0	0	0	1
c7	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0
c8	1	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0
c9	1	0	0	1	1	0	0	1	1	1	0	1	1	0	0	1
c10	1	0	1	0	1	0	1	0	1	1	1	1	1	0	1	0
c11	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0	0
c12	1	1	0	0	1	1	0	0	1	0	1	0	1	0	1	1
c13	1	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1
c14	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0
c15	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1
#(bit change)	1	3	7	15	1	2	6	14	1	2	4	8	1	6	10	10

In known methods for source encoding, the symbols or[, respectively,] parameters have been mapped to the natural binary code NBC after the source encoding QE and source quantization in an unsorted manner. In consequence, the source-controlled channel decoding CD was also only applied to such source-encoded bit positions b,i.

If the symbols or the symbol sequences SY consisting of symbols still contain redundant information, i.e. the relative frequencies of the symbol values c,j are distributed unevenly, or some symbols are correlated to one another, there is automatically also redundant information in some bit positions b,i. In elaborate simulations with simulation methods developed especially for this purpose it was found that, due to the uneven distribution of the symbol values c,j due to the deliberate use of certain binary mappings BM, the residual redundancy contained in the symbol sequences SY can be utilized particularly well for improving the error correction in the channel decoding CD.

The present invention makes particularly good use of the residual redundancy existing in the symbol sequence SY for decoding the binary values of the bit positions or, respectively, of bit positions b,i, because instead of employing some randomly selected mapping BM for the binary mapping, the symbols or parameters are first sorted in accordance with their probability and the natural binary code is allocated to the symbol structure thus produced.

Thus, the natural binary code (NBC) is allocated to the symbols sorted in accordance with their probability of occurrence in such a manner that a code word which has the first binary value at all bit positions, or a code word which has the second binary value at all bit positions, is allocated to the symbol occurring most

frequently, and a code word which exhibits the second binary value at all bit positions or a code word which exhibits the first binary value at all bit positions is allocated to the symbol occurring most rarely.

This leads to an efficient mapping of the symbol redundancy to the individual bit position redundancy; as a result, more redundant information about the binary values of the individual bit positions b,i can be utilized for error correction. In addition, more redundant information can be used for decoding the most significant bit than for decoding the second most significant bit. The decoding results can be particularly improved by a method according to the invention especially for mapping digital data or vector-quantized parameters to code words - as is shown by simulation results.

In the source-controlled channel decoding CD, the residual redundancy (uneven distribution) existing in the source-encoded symbol sequences SY can then be utilized more easily and more efficiently since the redundancy existing at the symbol level is thus converted into a redundancy (uneven distribution) existing at the bit level which can be used directly by the source-controlled channel decoder (e.g. Apri-VA). Using this method, an improved quality can be achieved in the transmission of the source signals QS (sound, voice, etc.). The additional computational effort for such sorting before binary mapping BM is low and usually can be neglected.

Such binary mapping BM can be implicitly integrated in the source encoder and decoder. For codecs which are already standardized such as the GSM full-rate/enhanced full-rate voice codec, however, it means a modification both in the receiver and in the transmitter. However, this modification is possible without any great hardware alteration. In the GSM system, it is only necessary, in

terms of infrastructure, to add the binary mapping and inverse mapping in the TRAU (transcoder and rate adapter unit), the BTS (base transceiver station), BSC (base station controller) etc. remain unchanged.

Figure 3 shows the frequency distribution of the symbol values c,j and the allocated binary code words bcw,j. It can be seen here that in the case of the NBC at the first bit position b1, the probability for the binary value "0" is very much greater than that for the binary value "1", especially under the condition that symbol c1 or c2 has been sent. This information can be utilized in the sense of a posteriori or a priori information in the source-controlled channel decoding in order to decide the binary value of the bit position b1 or, respectively, to determine the threshold used for this, and thus to make the decision more reliable.

Thus, the decoding can be improved further if information on the symbol value c,j probably transmitted is also used.

If the symbols have not been sorted before the binary mapping, the a posteriori or a priori information (that is to say the probability for a binary value "0") used in the source-controlled channel decoding would generally be less and the decoding of the bit positions could not be carried out so reliably.

In a variant of the embodiment of the invention, all or some of the bit positions of code words are interchanged after sorting and mapping symbols onto code words.

In an embodiment of the invention, the information consisting of symbol sequences SY is mapped to binary code words bcw,j having in each case a plurality of bit positions b,i in such a manner that even the correlation between the binary values of the corresponding bit positions b,i,k (or uq,k at frame level) and b,i,k+1 (or

uq,k+1 at frame level) of successive frames k, k+1 is large. In this arrangement, in particular, a correlation of the source bits is taken into consideration. The basic concept of this method consists in that corresponding symbols do not change very often between two successive frames and there is thus a redundancy in the transmission. This correlation between successive frames can be utilized especially well at the receiver end, using an APRI SOVA (a priori soft-output Viterbi algorithm) decoder if a binary mapping BM is selected in such a manner that the correlation between the binary values of the corresponding bit positions of the successive frames is large.

In elaborate simulations, the use of the GBC as binary mapping has thus been found to be particularly advantageous, especially if the symbols have a Gaussian or an anti-Gaussian distribution which is often the case.

In source-controlled channel decoding CD, the inter-frame correlation, that is to say the statistical dependence between temporally and/or spatially adjacent signal samples can also be utilized. To estimate the a priori/a posteriori information, for example, the empirical "HUK algorithm", which is described in "J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, Sept. 1995", or a method based on Kalman filters can also be used for source-controlled channel decoding.

In a further variant of the embodiment, the information consisting of symbol sequences SY is mapped to binary code words bcw,j having in each case a plurality of bit positions b,i in such a manner that, in the case of a wrongly detected binary value, the error in the detected symbol or, respectively, the output source signal QS is small. By means of a suitable binary mapping BM, the source signals will thus respond less

sensitively to co-channel interference. In elaborate simulations, the use of the FBC as binary mapping has thus been found to be particularly advantageous, especially if the symbols have a Gaussian or an anti-Gaussian distribution which is often the case.

Variants of the embodiment are also possible in which the binary mapping BM is selected in such a manner that a number of aspects of the variants described above are combined in the sense of a compromise.

To carry out the method explained above, a program-controlled signal processor integrated, for example, in radio equipment, such as a mobile station or base station of a mobile radio system, is provided which uses one of the methods described above for coding and/or decoding information to be transmitted.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of the inventor's contribution to the art.

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Case Number: P01,0052

International Application No. PCT/DE99/01993

International Filing Date: 01 July 1999

Title: METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION, SIGNAL PROCESSOR AND RADIO EQUIPMENT

Applicant: WEN XU

Enclosed are the following documents:

International Application as filed, drawings, attached; translation thereof
Submission of Substitute Specification including Red-lined version
Information Disclosure Statement
Submission of Ready to Publish Drawings
Request for Approval of Drawing Changes
PTO 1390 in duplicate;
Declaration
Assignment (separate envelope)
Government Filing Fee
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S P E C I F I C A T I O N

TITLE

"METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION, SIGNAL PROCESSOR AND RADIO EQUIPMENT"

BACKGROUND OF THE INVENTION

Field of the Invention

[Description
Method for coding, decoding and transmitting information, signal processor and radio equipment]

The present invention relates to a method for coding and decoding information, especially for digital transmission or storage.

Description of the Prior Art

Source signals or source information such as voice, sound, image and video signals almost always contain statistical redundancy, that is to say redundant information. This redundancy can be greatly reduced by source encoding, making it possible to transmit and/or store the source signal efficiently. This redundancy reduction eliminates redundant signal contents which are based on the prior knowledge of, for example, statistical parameters of the signal variation, before the transmission. After the transmission, these components are added to the signal again in the source decoding, so that no loss of quality can be detected objectively.

Due to the incomplete knowledge of the source signals or restrictions in the complexity of the source encoding method, the source encoding [can] usually only can be implemented in a suboptimum way, that is to say the compressed data still contain a certain redundancy even after the source encoding. In previous methods for source encoding, the source signals are frequently

compressed to form symbols or quantized parameters which are then mapped to binary code words in accordance with an allocation rule, the allocation rule having been selected more or less randomly until now.

On the other hand, it is usual to deliberately add redundancy again by channel encoding during the signal transmission in order to largely eliminate the effect of co-channel interference on the transmission. Additional redundant bits thus enable the receiver or, respectively, decoder to detect and possibly also to correct errors.

It has long been one of the basic [premisses] premises of information theory that source encoding and channel encoding can be carried out independently of one another in order to achieve an optimum result. According to this principle, the design of the source decoder [only] depends only on the source characteristics whereas the channel encoding arrangement should [only] depend only on the channel characteristics. This principle can be correct if the source encoder delivers statistically independent and thus uncorrelated symbols of equal probability and the decoding delay can be of any magnitude. In practical applications, however, these prerequisites are not met, as a rule. The output signal of the source encoder or, respectively, the symbol sequences output by it frequently exhibit a residual redundancy and, at the same time, the permissible delay is restricted, especially in voice transmission.

It is known to utilize this residual redundancy of the source-encoded symbol sequences in the so-called source-controlled channel decoding. In this process, the decoding process of the channel decoder is controlled, on the one hand, by the transmitted bits and, on the other hand, by a priori/a posteriori information on the

most probable value of some important source bits. The source information thus has an influence on the result of the channel decoding. In the case of the Viterbi algorithm decoding, this method is called an a priori Viterbi algorithm. When such a method is used, only the receiver needs to be modified. Thus, the printed document J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, September 1995, teaches to use the inter-frame correlation, that is to say the statistical dependence between temporally and/or spatially adjacent signal samples in the source-controlled channel decoding.

Investigations have also shown that there is residual redundancy not only between bits of successive frames but also between the bits of a parameter within a frame due to the uneven distribution of the parameter values which, in turn, is attributable to the non-stationary condition of the source signals.

SUMMARY OF THE INVENTION

The present invention has the object of achieving information transmission or information storage with the fewest possible errors and the least possible expenditure.

According to the invention, the abovementioned object is achieved [by the features of the independent claims].

[Accordingly, the invention is based on the concept of first] First sorting the symbols in accordance with their relative frequency and [to allocate] allocating the natural binary code to the sorting result.

The invention has the result that the error rate of the decoded bits can be reduced without additional expenditure, and thus information can be transmitted with fewer disturbances.

In the text which follows, the invention will be described in greater detail with reference to preferred illustrative embodiments. In this connection, it is especially the digital transmission of the information which is described. Nevertheless, the information can also be applied to the storage of information since the writing of information to a storage medium and the reading of information from a storage medium correspond to the sending of information and the receiving of information with regard to the present invention.

The term "decoding" is frequently used for describing the decoding of channel-encoded bit positions whilst the term "detection" is used if generally the binary values of a bit position are decided. Since the present invention is advantageously applicable to both cases, the term "decoding" also contains the process of detection within the context of the present patent application.

[The figures listed below are used for explaining the embodiments of the invention. In the figures:

Figure 1 shows a diagrammatic representation of a communication chain,

Figure 2 shows a diagrammatic representation of the connection between symbols and the source-encoded bit sequences in a frame structure,

Figure 3 shows a frequency distribution of the symbols and of the binary values depending on binary mapping.]

<u>Description of the Drawings</u>

<u>Figure 1 is a schematic representation of a communication chain constructed and operated in accordance with the invention.</u>

<u>Figure 2 is a diagram showing the relationship between symbols and the source-encoded bit sequences in a frame structure, in accordance with the invention.</u>

<u>Figure 3 illustrates the frequency distribution of the symbols and the binary values dependent on binary mapping, in accordance with the invention.</u>

Description of the Preferred Embodiments

Figure 1 shows a source Q which generates source signals QS which are compressed into symbol sequences SY consisting of symbols by a source encoder QE like the GSM full-rate voice encoder. Here, the symbols have one of the values c,j (symbol value). In parametric source encoding methods, the source signals QS (e.g. voice) generated by the source Q are subdivided into blocks (e.g. time frames) and these are processed separately. The source encoder QE generates quantized parameters (e.g. voice coefficients) which are also called symbols of a symbol sequence SY in the text which follows and which reflect the characteristics of the source in the current block in a certain manner (e.g. spectrum of the voice, filter parameter). These symbols have a certain symbol value c,j after the quantization.

Thus, for example, the GSM full-rate encoder generates 76 parameters, of which parameters 0 to 7 are the so-called LAR (logarithmic area ratio) coefficients which are generated during the LPC (linear prediction coding) analysis. Parameters 9, 26, 43 and 60 are similarity [figures] <u>values</u> for the so-called LTP (long-term prediction). Each frame also contains four XMAX coefficients (or parameters) from the so-called RPE (residual pulse excitation) analysis which change only little from frame to frame.

Due to the incomplete knowledge of the source signals or restrictions in the complexity of the source encoding method, the source encoding QE can usually be implemented only suboptimally, i.e. the symbol sequences SY contained in the compressed information still contain redundant information.

As shown in Figure 2, the symbols of the symbol sequence SY, or[, respectively,] the corresponding symbol values c,j are mapped by a binary mapping BM (allocation rule) which is frequently described as part of the source encoding QE, to a sequence BCW of binary code words bcw,j which in each case have a number of bit positions b,i. Thus, to each symbol value c,j, a different binary code word bcw,j is allocated which differ by having different binary values at one or more bit positions b,i. In this process, the index j identifies the different values of the symbols or the different code words and the indices i and, in the text which follows, k,q identify the position at which a corresponding value is located.

If these binary code words bcw,j are processed further, for example, successively as a sequence BCW of binary code words, a sequence u of source-encoded bit positions u_q is produced which can be embedded in a frame structure, each bit position u_q being permanently allocated to a particular bit position b,i of a particular code word bcw,j. Thus, a frame with 260 bit positions u_q is produced every 20 milliseconds, for example in GSM full-rate encoding.

Figure 2 shows a frame structure of a frame k produced in this manner. The source-encoded bit positions u_q have either the value "+1" or "-1" or[, respectively,] "0". The index 1 runs from 0 to Q-1 within a frame, Q being the number of source-encoded bit positions u_q in a frame. In each frame, the bit positions can be divided, for example, into three classes having different significance and sensitivity to co-channel interference.

The source-encoded bit sequences u are coded against co-channel interference in a channel encoder CE like a convolutional encoder, in such a manner that the lowest

bit-error probability occurs in the most important class. For this purpose, the 50 most significant bits (Class 1a) are first protected by 3 bits of a cyclic redundancy check (CRC). The next 132 significant bits (Class 1b) are regrouped with the aforementioned 53 bits and, together, convolutionally encoded with a 1/2 rate together with four tail bits. The 78 less significant bits (Class 2) are transmitted uncoded.

These bit sequences that have been x channel-encoded in this manner are processed further in a modulator, not shown, and are then transmitted via a transmission link CH. During the transmission, disturbances occur, for example, fading, described by a fading factor ak, and noise, described by the noise vector N0.

The transmission link CH is located between a transmitter and a receiver. If necessary, the receiver contains an antenna, not shown, for receiving the signals transmitted via the transmission link CH, a sampling device, a demodulator for demodulating the signals and an equalizer for eliminating the inter-symbol interference. These devices are also not shown in Figure 1 for reasons of simplification. Any possible interleaving and deinterleaving are also not shown.

The equalizer outputs received values of a received sequence y. Due to the interference in the transmission via the transmission link CH, the received values have values which deviate from "+1" and "-1", for example "+0.2" or "-3.7".

The channel encoding is cancelled in a channel decoder CD. For this purpose, the binary values of the individual received bit positions u_q and[, respectively,] b,i are decided on the basis of the received values of the received sequence y. Apart from the channel status

information CSI, the residual redundancy of the symbol sequences SY described above can be utilized in the so-called source-controlled or common channel decoding CD for correcting bit errors or, respectively, improving the decoding. In principle, there are two possibilities for this:

- In the sense of a priori information APRI, the redundant information on the frequency of the symbol values c,j, and thus also the frequency of the binary values of certain bit positions b,i, and the correlation of the symbols to each other and thus also the correlation of the binary values of certain bit positions b,i to each other, is utilized directly in the channel decoder CD in that, for example, this information is first determined by means of some test source signals in a test source encoder or, respectively, by means of a test source encoder, and this information is then stored in a storage unit allocated to the channel decoder CD and utilized for channel decoding in that it is used, for example, for determining a threshold from which, for example, the binary value "1" is decided for a value of the received sequence y.

- The redundant information on the frequency of the symbol values c,j, and thus also the frequency of the binary values of certain bit positions b,i, and the correlation of the symbols to each other and thus also the correlation of the binary values of certain bit positions b,i to each other, is determined after the channel decoding CD in the sense of a posteriori information. The a posteriori information APOI can be determined directly after

the channel decoder CD or after or during the source decoding QD.

Such a method is described in "J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, Sept. 1995", especially on pages 2451 and 2452, the decoding process of the channel decoder being controlled both by the transmitted code bits and by a priori/a posteriori information on the probable value of some significant source bits. In the case of the VA (Viterbi algorithm) decoding, this method has been called Apri-VA.

For the channel decoding CD, it is also possible to use, for example, a SOVA (soft-output Viterbi algorithm). A SOVA is an algorithm which outputs not only a decision value but, furthermore, also specifies the probability with which the decided value is present.

After the completed channel decoding CD, the received channel-decoded bit sequences u or, respectively, the binary code words bcw,j contained therein are mapped back [DB] in a reverse binary mapper BD onto received symbols of received symbol sequences SY which are then processed into source signals QS in the source decoding QD and are output at the information sink S.

In the text which follows, four possible different binary mappings BM are presented:

- Natural binary code NBC
- Folded binary code FBC
- Gray binary code GBC
- Minimum distance code MBC

These four binary mappings are shown by way of example with in each case 4 bit positions in the table below:

Symbol	Code word bcw,j NBC				Code word bcw,j FBC				Code word bcw,j GBC				Code word bcw,j MDC			
c,j	b3	b2	b1	b0	b3	b2	b1	b0	b3	b2	b1	b0	b3	b2	b1	b0
c0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1
c1	0	0	0	1	0	1	1	0	0	0	0	1	0	1	1	0
c2	0	0	1	0	0	1	0	1	0	0	1	1	0	1	0	1
c3	0	0	1	1	0	1	0	0	0	0	1	0	0	0	1	1
c4	0	1	0	0	0	0	1	1	0	1	1	0	0	1	0	0
c5	0	1	0	1	0	0	1	0	0	1	1	1	0	0	1	0
c6	0	1	1	0	0	0	0	1	0	1	0	1	0	0	0	1
c7	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0
c8	1	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0
c9	1	0	0	1	1	0	0	1	1	1	0	1	1	0	0	1
c10	1	0	1	0	1	0	1	0	1	1	1	1	1	0	1	0
c11	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0	0
c12	1	1	0	0	1	1	0	0	1	0	1	0	1	0	1	1
c13	1	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1
c14	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0
c15	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1
#(bit change)	1	3	7	15	1	2	6	14	1	2	4	8	1	6	10	10

In [previously] known methods for source encoding, the symbols or[, respectively,] parameters have been mapped to the natural binary code NBC after the source encoding QE and source quantization in an unsorted manner. In consequence, the source-controlled channel decoding CD was also only applied to such source-encoded bit positions b,i.

If the symbols or[, respectively,] the symbol sequences SY consisting of symbols still contain redundant information, i.e. the relative frequencies of the symbol values c,j are distributed unevenly, or some symbols are correlated to one another, there is automatically also redundant information in some bit positions b,i. In elaborate simulations with simulation methods developed especially for this purpose it was found that, due to the uneven distribution of the symbol values c,j due to the deliberate use of certain binary mappings BM, the residual redundancy contained in the symbol sequences SY can be utilized particularly well for

improving the error correction in the channel decoding CD.

The present invention makes particularly good use of the residual redundancy existing in the symbol sequence SY for decoding the binary values of the bit positions or, respectively, of bit positions b,i, [in that it is not] because instead of employing some randomly selected mapping BM [which is selected but, instead,] for the binary mapping, the symbols or parameters[, respectively,] are first sorted in accordance with their probability and the natural binary code is allocated to the symbol structure thus produced.

Thus, the natural binary code (NBC) is allocated to the symbols sorted in accordance with their probability of occurrence in such a manner that a code word which has the first binary value at all bit positions, or a code word which has the second binary value at all bit positions, is allocated to the symbol occurring most frequently, and a code word which exhibits the second binary value at all bit positions or a code word which exhibits the first binary value at all bit positions is allocated to the symbol occurring most rarely.

This leads to an efficient mapping of the symbol redundancy to the individual bit position redundancy; as a result, more redundant information about the binary values of the individual bit positions b,i can be utilized for error correction. In addition, more redundant information can be used for decoding the most significant bit than for decoding the second most significant bit. The decoding results can be particularly improved by a method according to the invention especially for mapping digital data or vector-quantized parameters to code words - as is shown by simulation results.

In the source-controlled channel decoding CD, the residual redundancy (uneven distribution) existing in the source-encoded symbol sequences SY can then be utilized more easily and more efficiently since the redundancy existing at the symbol level is thus converted into a redundancy (uneven distribution) existing at the bit level which can be used directly by the source-controlled

channel decoder (e.g. Apri-VA). Using this method, an improved quality can be achieved in the transmission of the source signals QS (sound, voice, etc.). The additional computational effort for such sorting before binary mapping BM is low and <u>usually</u> can be [usually] neglected.

Such binary mapping BM can be implicitly integrated in the source encoder and decoder. For codecs which are already standardized such as the GSM full-rate/enhanced full-rate voice codec, however, it means a modification both in the receiver and in the transmitter. However, this modification is possible without any great hardware alteration. In the GSM system, it is only necessary, in terms of infrastructure, to add the binary mapping and inverse mapping in the TRAU (transcoder and rate adapter unit), the BTS (base transceiver station), BSC (base station controller) etc. remain unchanged.

Figure 3 shows the frequency distribution of the symbol values c,j and the allocated binary code words bcw,j. It can be seen here that in the case of the NBC at the first bit position b1, the probability for the binary value "0" is very much greater than that for the binary value "1", especially under the condition that symbol c1 or c2 has been sent. This information can be utilized in the sense of a posteriori or a priori information in the source-controlled channel decoding in order to decide the binary value of the bit position b1 or, respectively, to determine the threshold used for this, and thus to make the decision more reliable.

Thus, the decoding can be improved further if information on the symbol value c,j probably transmitted is also used.

If the symbols have not been sorted before the binary mapping, the a posteriori or a priori information (that is to say the probability for a binary value "0") used in the source-controlled channel decoding would generally be less and the decoding of the bit positions could not be carried out so reliably.

In a variant of the embodiment of the invention, all or some of the bit positions of code words are

interchanged after sorting and mapping symbols onto code words.

In an embodiment of the invention, the information consisting of symbol sequences SY is mapped to binary code words bcw,j having in each case a plurality of bit positions b,i in such a manner that even the correlation between the binary values of the corresponding bit positions b,i,k (or uq,k at frame level) and b,i,k+1 (or uq,k+1 at frame level) of successive frames k, k+1 is large. In this arrangement, in particular, a correlation of the source bits is taken into consideration. The basic concept of this method consists in that corresponding symbols do not change very often between two successive frames and there is thus a redundancy in the transmission. This correlation between successive frames can be utilized especially well at the receiver end, using an APRI SOVA (a priori soft-output Viterbi algorithm) decoder if a binary mapping BM is selected in such a manner that the correlation between the binary values of the corresponding bit positions of the successive frames is large.

In elaborate simulations, the use of the GBC as binary mapping has thus been found to be particularly advantageous, especially if the symbols have a Gaussian or an anti-Gaussian distribution which is often the case.

In source-controlled channel decoding CD, the inter-frame correlation, that is to say the statistical dependence between temporally and/or spatially adjacent signal samples can also be utilized. To estimate the a priori/a posteriori information, for example, the empirical "HUK algorithm", which is described in "J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, Sept. 1995", or a method based on Kalman filters can also be used for source-controlled channel decoding.

In a further variant of the embodiment, the information consisting of symbol sequences SY is mapped to binary code words bcw,j having in each case a plurality of bit positions b,i in such a manner that, in the case of a wrongly detected binary value, the error in the detected symbol or, respectively, the output

source signal QS is small. By means of a suitable binary mapping BM, the source signals will thus respond less sensitively to co-channel interference. In elaborate simulations, the use of the FBC as binary mapping has thus been found to be particularly advantageous, especially if the symbols have a Gaussian or an anti-Gaussian distribution which is often the case.

Variants of the embodiment are also possible in which the binary mapping BM is selected in such a manner that a number of aspects of the variants described above are combined in the sense of a compromise.

To carry out the method explained above, a program-controlled signal processor integrated, for example, in radio equipment, such as a mobile station or base station of a mobile radio system, is provided which uses one of the methods described above for coding and/or decoding information to be transmitted.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of the inventor's contribution to the art.

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Description

Method for coding, decoding and transmitting information, signal processor and radio equipment

The present invention relates to a method for coding and decoding information, especially for digital transmission or storage.

Source signals or source information such as voice, sound, image and video signals almost always contain statistical redundancy, that is to say redundant information. This redundancy can be greatly reduced by source encoding, making it possible to transmit and/or store the source signal efficiently. This redundancy reduction eliminates redundant signal contents which are based on the prior knowledge of, for example, statistical parameters of the signal variation, before the transmission. After the transmission, these components are added to the signal again in the source decoding, so that no loss of quality can be detected objectively.

Due to the incomplete knowledge of the source signals or restrictions in the complexity of the source encoding method, the source encoding can usually only be implemented in a suboptimum way, that is to say the compressed data still contain a certain redundancy even after the source encoding. In previous methods for source encoding, the source signals are frequently compressed to form symbols or quantized parameters which are then mapped to binary code words in accordance with an allocation rule, the allocation rule having been selected more or less randomly until now.

On the other hand, it is usual to deliberately add redundancy again by channel encoding during the signal transmission in order to largely eliminate the effect of co-channel interference on the transmission. Additional

redundant bits thus enable the receiver or, respectively, decoder to detect and possibly also to correct errors.

It has long been one of the basic premisses of information theory that source encoding and channel encoding can be carried out independently of one another in order to achieve an optimum result. According to this principle, the design of the source decoder only depends on the source characteristics whereas the channel encoding arrangement should only depend on the channel characteristics. This principle can be correct if the source encoder delivers statistically independent and thus uncorrelated symbols of equal probability and the decoding delay can be of any magnitude. In practical applications, however, these prerequisites are not met, as a rule. The output signal of the source encoder or, respectively, the symbol sequences output by it frequently exhibit a residual redundancy and, at the same time, the permissible delay is restricted, especially in voice transmission.

It is known to utilize this residual redundancy of the source-encoded symbol sequences in the so-called source-controlled channel decoding. In this process, the decoding process of the channel decoder is controlled, on the one hand, by the transmitted bits and, on the other hand, by a priori/a posteriori information on the most probable value of some important source bits. The source information thus has an influence on the result of the channel decoding. In the case of the Viterbi algorithm decoding, this method is called an a priori Viterbi algorithm. When such a method is used, only the receiver needs to be modified. Thus, the printed document J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, September 1995, teaches to use the inter-frame correlation, that is to say the

statistical dependence between temporally and/or spatially adjacent signal samples in the source-controlled channel decoding.

Investigations have also shown that there is residual redundancy not only between bits of successive frames but also between the bits of a parameter within a frame due to the uneven distribution of the parameter values which, in turn, is attributable to the non-stationary condition of the source signals.

The present invention has the object of achieving information transmission or information storage with the fewest possible errors and the least possible expenditure.

According to the invention, the abovementioned object is achieved by the features of the independent claims.

Accordingly, the invention is based on the concept of first sorting the symbols in accordance with their relative frequency and to allocate the natural binary code to the sorting result.

The invention has the result that the error rate of the decoded bits can be reduced without additional expenditure, and thus information can be transmitted with fewer disturbances.

In the text which follows, the invention will be described in greater detail with reference to preferred illustrative embodiments. In this connection, it is especially the digital transmission of the information which is described. Nevertheless, the information can also be applied to the storage of information since the writing of information to a storage medium and the reading of information from a storage medium correspond to the sending of information and the receiving of information with regard to the present invention.

The term "decoding" is frequently used for describing the decoding of channel-encoded bit positions whilst the term "detection" is used if generally the binary values of a bit position are decided. Since the present invention is advantageously applicable to both cases,

the term "decoding" also contains the process of detection within the context of the present patent application.

The figures listed below are used for explaining the embodiments of the invention. In the figures:

Figure 1 shows a diagrammatic representation of a communication chain,

Figure 2 shows a diagrammatic representation of the connection between symbols and the source-encoded bit sequences in a frame structure,

Figure 3 shows a frequency distribution of the symbols and of the binary values depending on binary mapping.

Figure 1 shows a source Q which generates source signals QS which are compressed into symbol sequences SY consisting of symbols by a source encoder QE like the GSM full-rate voice encoder. Here, the symbols have one of the values c,j (symbol value). In parametric source encoding methods, the source signals QS (e.g. voice) generated by the source Q are subdivided into blocks (e.g. time frames) and these are processed separately. The source encoder QE generates quantized parameters (e.g. voice coefficients) which are also called symbols of a symbol sequence SY in the text which follows and which reflect the characteristics of the source in the current block in a certain manner (e.g. spectrum of the voice, filter parameter). These symbols have a certain symbol value c,j after the quantization.

Thus, for example, the GSM full-rate encoder generates 76 parameters, of which parameters 0 to 7 are

the so-called LAR (logarithmic area ratio) coefficients which are generated during the LPC (linear prediction coding) analysis. Parameters

9, 26, 43 and 60 are similarity figures for the so-called LTP (long-term prediction). Each frame also contains four XMAX coefficients (or parameters) from the so-called RPE (residual pulse excitation) analysis which change only little from frame to frame.

Due to the incomplete knowledge of the source signals or restrictions in the complexity of the source encoding method, the source encoding QE can usually be implemented only suboptimally, i.e. the symbol sequences SY contained in the compressed information still contain redundant information.

As shown in Figure 2, the symbols of the symbol sequence SY or, respectively, the corresponding symbol values c,j are mapped by a binary mapping BM (allocation rule) which is frequently described as part of the source encoding QE, to a sequence BCW of binary code words bcw,j which in each case have a number of bit positions b,i. Thus, to each symbol value c,j, a different binary code word bcw,j is allocated which differ by having different binary values at one or more bit positions b,i. In this process, the index j identifies the different values of the symbols or the different code words and the indices i and, in the text which follows, k,q identify the position at which a corresponding value is located.

If these binary code words bcw,j are processed further, for example, successively as a sequence BCW of binary code words, a sequence u of source-encoded bit positions u_q is produced which can be embedded in a frame structure, each bit position u_q being permanently allocated to a particular bit position b,i of a particular code word bcw,j. Thus, a frame with 260 bit positions u_q is produced every 20 milliseconds, for example in GSM full-rate encoding.

Figure 2 shows a frame structure of a frame k produced in this manner. The source-encoded bit positions u_q have either the

value "+1" or "-1" or, respectively, "0". The index 1 runs from 0 to Q-1 within a frame, Q being the number of source-encoded bit positions u_q in a frame. In each frame, the bit positions can be divided, for example, into three classes having different significance and sensitivity to co-channel interference.

The source-encoded bit sequences u are coded against co-channel interference in a channel encoder CE like a convolutional encoder, in such a manner that the lowest bit-error probability occurs in the most important class. For this purpose, the 50 most significant bits (Class 1a) are first protected by 3 bits of a cyclic redundancy check (CRC). The next 132 significant bits (Class 1b) are regrouped with the aforementioned 53 bits and, together, convolutionally encoded with a 1/2 rate together with four tail bits. The 78 less significant bits (Class 2) are transmitted uncoded.

These bit sequences x channel-encoded in this manner are processed further in a modulator, not shown, and are then transmitted via a transmission link CH. During the transmission, disturbances occur, for example, fading, described by a fading factor ak, and noise, described by the noise vector N0.

The transmission link CH is located between a transmitter and a receiver. If necessary, the receiver contains an antenna, not shown, for receiving the signals transmitted via the transmission link CH, a sampling device, a demodulator for demodulating the signals and an equalizer for eliminating the inter-symbol interference. These devices are also not shown in Figure 1 for reasons of simplification. Any possible interleaving and deinterleaving are also not shown.

The equalizer outputs received values of a received sequence y. Due to the interference in the transmission

via the transmission link CH, the received values have values which deviate from "+1" and "-1", for example "+0.2" or "-3.7".

The channel encoding is cancelled in a channel decoder CD. For this purpose, the binary values of the individual received bit positions $\underline{u}_q$ and, respectively, $\underline{b,i}$ are decided on the basis of the received values of the received sequence y. Apart from the channel status information CSI, the residual redundancy of the symbol sequences SY described above can be utilized in the so-called source-controlled or common channel decoding CD for correcting bit errors or, respectively, improving the decoding. In principle, there are two possibilities for this:

- In the sense of a priori information APRI, the redundant information on the frequency of the symbol values c,j, and thus also the frequency of the binary values of certain bit positions b,i, and the correlation of the symbols to each other and thus also the correlation of the binary values of certain bit positions b,i to each other, is utilized directly in the channel decoder CD in that, for example, this information is first determined by means of some test source signals in a test source encoder or, respectively, by means of a test source encoder, and this information is then stored in a storage unit allocated to the channel decoder CD and utilized for channel decoding in that it is used, for example, for determining a threshold from which, for example, the binary value "1" is decided for a value of the received sequence y.
- The redundant information on the frequency of the symbol values c,j, and thus also the frequency of the binary values of certain bit positions b,i, and the correlation of the symbols to each other and thus also the correlation of the binary values of certain bit positions b,i to each other, is determined after

the channel decoding CD in the sense of a posteriori information. The a posteriori information APOI can be determined directly

after the channel decoder CD or after or during the source decoding QD.

Such a method is described in "J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, Sept. 1995", especially on pages 2451 and 2452, the decoding process of the channel decoder being controlled both by the transmitted code bits and by a priori/a posteriori information on the probable value of some significant source bits. In the case of the VA (Viterbi algorithm) decoding, this method has been called Apri-VA.

For the channel decoding CD, it is also possible to use, for example, a SOVA (soft-output Viterbi algorithm). A SOVA is an algorithm which outputs not only a decision value but, furthermore, also specifies the probability with which the decided value is present.

After the completed channel decoding CD, the received channel-decoded bit sequences <u>u</u> or, respectively, the binary code words <u>bcw,j</u> contained therein are mapped back DB onto received symbols of received symbol sequences <u>SY</u> which are then processed into source signals <u>QS</u> in the source decoding QD and are output at the information sink S.

In the text which follows, four possible different binary mappings BM are presented:

- Natural binary code NBC
- Folded binary code FBC
- Gray binary code GBC
- Minimum distance code MBC

These four binary mappings are shown by way of example with in each case 4 bit positions in the table below:

Symbol	Code word bcw,j NBC				Code word bcw,j FBC				Code word bcw,j GBC				Code word bcw,j MDC			
c,j	b3	b2	b1	b0	b3	b2	b1	b0	b3	b2	b1	b0	b3	b2	b1	b0
c0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1
c1	0	0	0	1	0	1	1	0	0	0	0	1	0	1	1	0
c2	0	0	1	0	0	1	0	1	0	0	1	1	0	1	0	1
c3	0	0	1	1	0	1	0	0	0	0	1	0	0	0	1	1
c4	0	1	0	0	0	0	1	1	0	1	1	0	0	1	0	0
c5	0	1	0	1	0	0	1	0	0	1	1	1	0	0	1	0
c6	0	1	1	0	0	0	0	1	0	1	0	1	0	0	0	1
c7	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0
c8	1	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0
c9	1	0	0	1	1	0	0	1	1	1	0	1	1	0	0	1
c10	1	0	1	0	1	0	1	0	1	1	1	1	1	0	1	0
c11	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0	0
c12	1	1	0	0	1	1	0	0	1	0	1	0	1	0	1	1
c13	1	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1
c14	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0
c15	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1
#(bit change)	1	3	7	15	1	2	6	14	1	2	4	8	1	6	10	10

In previously known methods for source encoding, the symbols or, respectively, parameters have been mapped to the natural binary code NBC after the source encoding QE and source quantization in an unsorted manner. In consequence, the source-controlled channel decoding CD was also only applied to such source-encoded bit positions b,i.

If the symbols or, respectively, the symbol sequences SY consisting of symbols still contain redundant information, i.e. the relative frequencies of the symbol values c,j are distributed unevenly, or some symbols are correlated to one another,

there is automatically also redundant information in some bit positions b,i. In elaborate simulations with simulation methods developed especially for this purpose it was found that, due to the uneven distribution of the symbol values c,j due to the deliberate use of certain binary mappings BM, the residual redundancy contained in the symbol sequences SY can be utilized particularly well for improving the error correction in the channel decoding CD.

The present invention makes particularly good use of the residual redundancy existing in the symbol sequence SY for decoding the binary values of the bit positions or, respectively, of bit positions b,i in that it is not some randomly selected mapping BM which is selected but, instead, for the binary mapping, the symbols or parameters, respectively, are first sorted in accordance with their probability and the natural binary code is allocated to the symbol structure thus produced.

Thus, the natural binary code (NBC) is allocated to the symbols sorted in accordance with their probability of occurrence in such a manner that a code word which has the first binary value at all bit positions, or a code word which has the second binary value at all bit positions, is allocated to the symbol occurring most frequently, and a code word which exhibits the second binary value at all bit positions or a code word which exhibits the first binary value at all bit positions is allocated to the symbol occurring most rarely.

This leads to an efficient mapping of the symbol redundancy to the individual bit position redundancy; as a result, more redundant information about the binary values of the individual bit positions b,i can be utilized for error correction. In addition, more redundant information can be used for decoding the most significant bit than for decoding the second most significant bit. The decoding results can be particularly improved

by a method according to the invention especially for mapping digital data or vector-quantized parameters to code words - as is shown by simulation results.

In the source-controlled channel decoding CD, the residual redundancy (uneven distribution) existing in the source-encoded symbol sequences SY can then be utilized more easily and more efficiently since the redundancy existing at the symbol level is thus converted into a redundancy (uneven distribution) existing at the bit level which can be used directly by the source-controlled channel decoder (e.g. Apri-VA). Using this method, an improved quality can be achieved in the transmission of the source signals QS (sound, voice, etc.). The additional computational effort for such sorting before binary mapping BM is low and can be usually neglected.

Such binary mapping BM can be implicitly integrated in the source encoder and decoder. For codecs which are already standardized such as the GSM full-rate/enhanced full-rate voice codec, however, it means a modification both in the receiver and in the transmitter. However, this modification is possible without any great hardware alteration. In the GSM system, it is only necessary, in terms of infrastructure, to add the binary mapping and inverse mapping in the TRAU (transcoder and rate adapter unit), the BTS (base transceiver station), BSC (base station controller) etc. remain unchanged.

Figure 3 shows the frequency distribution of the symbol values c,j and the allocated binary code words bcw,j. It can be seen here that in the case of the NBC at the first bit position b1, the probability for the binary value "0" is very much greater than that for the binary value "1", especially under the condition that symbol c1 or c2 has been sent. This information can be utilized in the sense of a posteriori or a priori information in the source-controlled channel decoding

in order to decide the binary value of the bit position b1 or, respectively, to determine the threshold used for this, and thus to make the decision more reliable.

Thus, the decoding can be improved further if information on the symbol value c,j probably transmitted is also used.

If the symbols have not been sorted before the binary mapping, the a posteriori or a priori information (that is to say the probability for a binary value "0") used in the source-controlled channel decoding would generally be less and the decoding of the bit positions could not be carried out so reliably.

In a variant of the embodiment of the invention, all or some of the bit positions of code words are interchanged after sorting and mapping symbols onto code words.

In an embodiment of the invention, the information consisting of symbol sequences SY is mapped to binary code words bcw,j having in each case a plurality of bit positions b,i in such a manner that even the correlation between the binary values of the corresponding bit positions b,i,k (or uq,k at frame level) and b,i,k+1 (or uq,k+1 at frame level) of successive frames k, k+1 is large. In this arrangement, in particular, a correlation of the source bits is taken into consideration. The basic concept of this method consists in that corresponding symbols do not change very often between two successive frames and there is thus a redundancy in the transmission. This correlation between successive frames can be utilized especially well at the receiver end, using an APRI SOVA (a priori soft-output Viterbi algorithm) decoder if a binary mapping BM is selected in such a manner that the correlation between the binary values of the corresponding bit positions of the successive frames is large.

In elaborate

simulations, the use of the GBC as binary mapping has thus been found to be particularly advantageous, especially if the symbols have a Gaussian or an anti-Gaussian distribution which is often the case.

In source-controlled channel decoding CD, the inter-frame correlation, that is to say the statistical dependence between temporally and/or spatially adjacent signal samples can also be utilized. To estimate the a priori/a posteriori information, for example, the empirical "HUK algorithm", which is described in "J. Hagenauer, "Source-controlled channel decoding", IEEE Trans. Commun., Vol. 43, pages 2449-2457, Sept. 1995", or a method based on Kalman filters can also be used for source-controlled channel decoding.

In a further variant of the embodiment, the information consisting of symbol sequences SY is mapped to binary code words bcw,j having in each case a plurality of bit positions b,i in such a manner that, in the case of a wrongly detected binary value, the error in the detected symbol or, respectively, the output source signal QS is small. By means of a suitable binary mapping BM, the source signals will thus respond less sensitively to co-channel interference. In elaborate simulations, the use of the FBC as binary mapping has thus been found to be particularly advantageous, especially if the symbols have a Gaussian or an anti-Gaussian distribution which is often the case.

Variants of the embodiment are also possible in which the binary mapping BM is selected in such a manner that a number of aspects of the variants described above are combined in the sense of a compromise.

To carry out the method explained above, a program-

controlled signal processor integrated, for example, in radio equipment, such as a mobile station or base station of a mobile radio system, is provided which uses one of the methods described above for coding and/or decoding information to be transmitted.

Patent claims

1. A method for coding information consisting of symbol sequences (SY), symbols occurring with different probabilities, in which

- symbols are mapped to binary code words (bcw,j) having in each case a plurality of bit positions (b,i) the mapping taking place in such a manner that

- the natural binary code (NBC) is allocated to symbols sorted in accordance with their probability of occurrence.

2. The method as claimed in claim 1, in which

- at least an essential proportion of the symbols or all symbols are sorted in accordance with their probability, and

- the natural binary code (NBC) is allocated to at least an essential proportion of symbols sorted in this manner or to all symbols sorted in this manner or to all symbols.

3. The method as claimed in one of the preceding claims, in which the natural binary code (NBC) is allocated to symbols sorted in accordance with their probability of occurrence, in such a manner that

- a code word with exhibits the first binary value at all bit positions or a code word which exhibits the second binary value at all bit positions is allocated to the symbol occurring most frequently, and

- a code word which exhibits the second binary value at all bit positions or a code word which exhibits the first binary value at all bit positions is allocated to the symbol occurring most rarely.

4. The method as claimed in one of the preceding claims, in which the symbol sequences (SY) originate from a source encoding (QE).

5. The method as claimed in one of the preceding claims, in which

bit positions (b,i) of code words (bcw,j) resulting from the mapping are interchanged.

6. The method for decoding information, in which the information consisting of symbol sequences has been coded in accordance with one of the preceding claims and the redundant information contained in the symbol sequences (SY) or, respectively, the redundant information contained in the bit positions of the associated code words is used as a priori and/or a posteriori information in the determination of the values of the bit positions (b,i).

7. A method for transmitting information in which the information is coded as claimed in one of claims 1 to 5 and decoded as claimed in claim 6.

8. A signal processor comprising means for coding information as claimed in one of claims 1 to 5.

9. A signal processor comprising means for decoding information as claimed in claim 6.

10. Radio equipment containing a signal processor comprising means for coding information as claimed in one of claims 1 to 5 and means for decoding information as claimed in claim 6.

Abstract

Method for coding, decoding and transmitting information, signal processor and radio equipment

A method for coding information in which the symbols of information consisting of symbol sequences are first sorted in accordance with their probability, then mapped to the natural binary code and thus the redundant information contained in the symbol sequences can be used for decoding the bit positions.

Figure 1

GR 98 P 2689

Key to figures

Figure 2

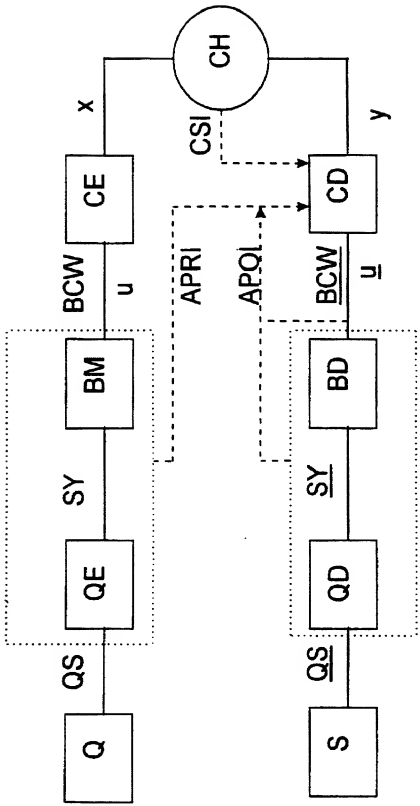
Rahmen = Frame

Frame

09/787997

1/3

FIG 1



09/787997

2/3

FIG 2

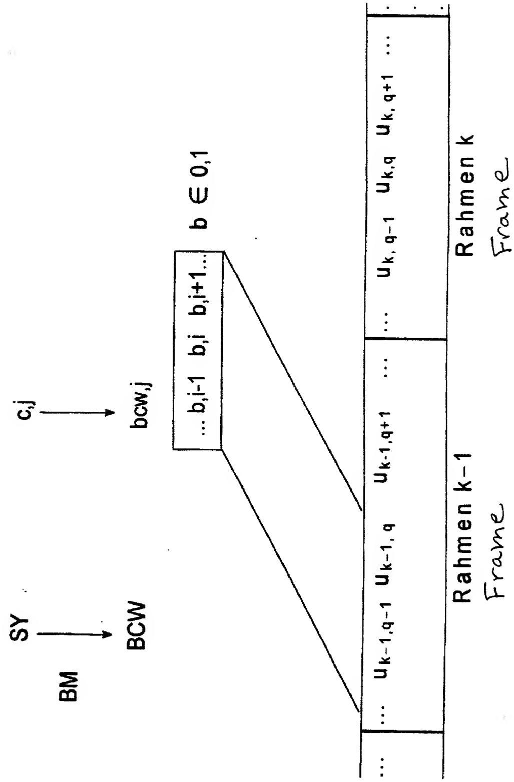
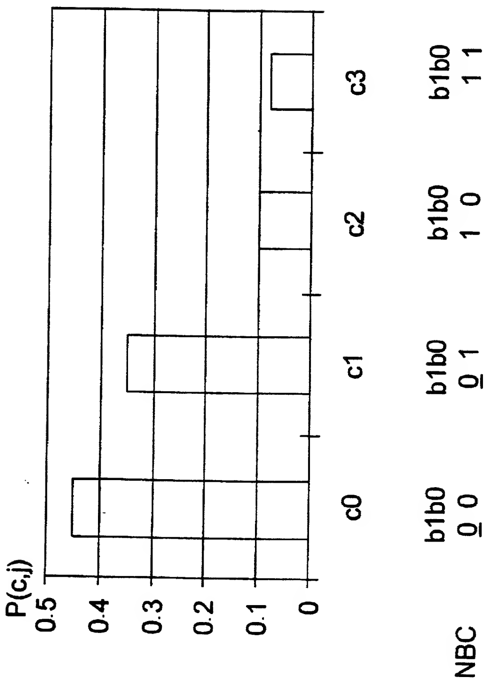


FIG 3



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German Language Declaration

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____
____

the specification of which

(check one)

☐ is attached hereto.

☐ was filed on ____________ as PCT international application
PCT Application No. ____________
and was amended on ____________
(if applicable)

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Prior foreign appplications
Priorität beansprucht

Priority Claimed

198 43 981.4	Germany	24. September 1998	☒	☐
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	Yes Ja	No Nein
			☐	☐
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	Yes Ja	No Nein
			☐	☐
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	Yes Ja	No Nein

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(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhangig, aufgegeben)	(Status) (patented, pending, abandoned)
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And I hereby appoint

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IN THE UNITED STATES DESIGNATED OFFICE
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CHANGE OF ADDRESS OF APPLICANTS' REPRESENTATIVES

APPLICANT(S): WEN XU

ATTORNEY DOCKET NO. P01,0052

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INVENTION: METHOD FOR CODING, DECODING AND TRANSMITTING INFORMATION, SIGNAL PROCESSOR AND RADIO EQUIPMENT

Assistant Commissioner for Patents

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Members of the firm of Hill & Simpson designated on the original Power of Attorney have merged in the firm of Schiff Hardin & Waite. All future correspondence for the above-referenced application therefore shoud be sent to the following address:

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